ON THE FLORA OF THE FRONTIER FORMATION OF SOUTHWESTERN WYOMING[1]

HENRY N. ANDREWS
Instructor, Henry Shaw School of Botany of Washington University

AND CORTLAND S. PEARSALL
Geologist to the Tunnel Division, Metropolitan Water Commission, Boston, Mass.

Introduction

In 1917 Dr. F. H. Knowlton described a small flora from the Upper Cretaceous Frontier formation of southwestern Wyoming. Attracted by that author's figures of *Microtaenia paucifolia* (Hall) Knowlton, we made a small collection of the fructifications in the summer of 1934. Nothing of exceptional note was obtained at that time and our collections did not receive immediate study. In the summer of 1939, when the senior author revisited the locality, certain undescribed fructifications were discovered, but as time did not permit extensive exploration we returned the following summer and prospected the outcrop carefully for about 4 miles north and 1½ miles south of Little Muddy Creek. We were fortunate in obtaining nearly complete fertile pinnae referable to *Anemia Fremonti* Knowlton and in finding certain other fossil plants or parts thereof not previously described.

The plant-bearing horizon was originally discovered by Capt. John C. Fremont in 1843 while exploring for a better emigrant route to the Northwest. Fremont's collections were turned over to James Hall, New York State Paleontologist, who published descriptions in 1845. Other collections were made at later dates by members of the U. S. Geological Survey and were presented in Knowlton's paper of 1917.

Of the 25 described species composing the flora there are 7 ferns, 1 *Equisetum,* and 17 Angiosperms, the latter including *Quercus, Ficus, Salix, Aralia, Dewalquea* and *Cinnamomum.*

[1] A study financed in part by a grant from the Penrose Fund of the American Philosophical Society of Philadelphia.

Issued April 28, 1941.

Certain of these genera are undoubtedly valid; others are questionable as Knowlton himself admitted. The present paper will not be concerned with the Angiosperm element of the flora.

Geology

The section of the Frontier formation discussed in this paper is situated in the southwestern corner of Wyoming, about 15 miles south of the town of Kemmerer, in the vicinity of Cumberland Gap. The formation, which consists of a series of light-colored coal-bearing sandstones and shales approximately 2500 feet thick, extends for many miles both north and south of Cumberland Gap and is characterized by a series of prominent hogbacks. It is underlain by the dark-colored oil-bearing Aspen shales, and overlain by the dark-colored Hilliard shales. The most prominent hogback is formed by the Oyster Ridge member, which is an oyster *(Ostrea soleniscus)*-bearing sandstone about 200 feet thick near the top of the formation. Numerous coal seams are contained in the lower half of the formation.

The plant material was collected from a series of white to light blue-gray shales about 50 feet thick. These are located stratigraphically about 75 feet above the generally accepted base of the formation. Small sandstone beds directly above the plant-bearing shales contain a great deal of silicified wood. The plant shales break poorly along the bedding plane and are in the nature of argillite which in thin section is a typical clastic, fine-grained sediment consisting of approximately 70 per cent clay minerals, 28 per cent angular quartz, 1 per cent feldspar, 1 per cent zircon, hornblende, biotite and carbonate (Veatch, '07).

Methods

The cellulose transfer technique proved very satisfactory with the compressions of the fertile pinnae of *Anemia Fremonti* (see p. 168). Fragmentary specimens were selected in which the fructifications appeared to be well preserved. A rather heavy coat of nitrocellulose solution (Darrah's formula) was then applied to the surface of the matrix and exposed plant material. The entire specimen was then placed in hydrofluoric acid. It was found advisable not to cut away the apparently excess rock in back of the compression because in some cases this contained additional fragments of the fructifications which dissolve away from the rock and serve as excellent material for maceration.

The disintegration of the rock can be accelerated by removing the block from the acid each day and scraping away the partially dissolved matrix. Specimens as thick as 1½ inches were treated in this way, and the time for complete dissolution

TABLE I

GEOLOGIC COLUMN SHOWING THE RELATION OF THE FRONTIER FORMATION TO OTHER CRETACEOUS FORMATIONS (FROM VEATCH, '07, TABLE FACING p. 501)

<table>
<tr><th colspan="3">System and Group</th><th>Formation</th></tr>
<tr><td colspan="3">Eocene</td><td>Unconformity</td></tr>
<tr><td rowspan="7">Cretaceous</td><td colspan="2">Lower Laramie</td><td>Adaville formation, with basal Lazeart sandstone</td></tr>
<tr><td colspan="2">Montana</td><td rowspan="2">Hilliard formation</td></tr>
<tr><td rowspan="5">Colorado</td><td>Niobrara</td></tr>
<tr><td rowspan="2">Benton</td><td>Frontier formation with the Oyster Ridge sandstone member</td></tr>
<tr><td>Aspen formation</td></tr>
<tr><td rowspan="2">Bear River, Dakota?, and Lower Cretaceous?</td><td>Bear River formation</td></tr>
<tr><td>Beckwith formation</td></tr>
<tr><td colspan="3">Jurassic</td><td>Twin Creek formation</td></tr>
</table>

of the rock was in no case longer than 10 days. The last fragments of matrix may be removed with a camel's-hair brush under water. This transparent celloidin technique had, with our material, two very important advantages: first, the back side of the fossil may be studied as well as the front when it is mounted; and second, much better photographs could be obtained than when the rather grayish rock matrix constituted the background. If figs. 2 or 3 (photographs of specimens in the matrix) be compared with figs. 1 and 5 (photographs of specimens transferred to celloidin) the difference is quite apparent.

Maceration of the isolated fragments of the fructifications was done in the usual way with strong nitric acid and potassium chlorate.

SCHIZAEACEAE

Anemia Fremonti Knowlton forma **fertilis** Andrews, forma nov.

It is not often that well-preserved spore-bearing parts can be referred with certainty to any of the numerous sterile fern species that go to compose the fossil record. Associated with foliage which Knowlton ('17) described as *A. Fremonti* were found fructifications of an undoubted schizaeaceous nature and, as will be made clear, in all probability referable to the genus *Anemia*. The significance of the association of fertile and sterile parts will be considered after the former have been described.

The most complete specimen that we have found is shown in fig. 3. It is pinnately compound, the branching taking place in one plane. Figures 1, 2, 4, 5 are isolated primary branches (as will be shown below, these are secondary pinnae, according to usual fern terminology) photographed at a higher magnification. The secondary branches, which are quite short, bear two or three flattened globose bodies, two being borne laterally and a third terminating the branch. In figs. 2 and 5 only one of these bodies may be seen attached to each secondary branch; in fig. 4 two may be seen on some branches while others have only one, both the terminal and a lateral having been lost.

Well-preserved fragments of the primary branches isolated from the matrix show three in all cases.

Within one minute after such fragments had been treated with strong nitric acid and potassium chlorate each of the small black bodies opened up into about seven ''valves.'' If maceration was not then stopped by diluting the acid with water, the fragments very soon almost completely disintegrated. Due to the extreme fragility of the material at this point it has not been possible to prepare permanent preparations nor to obtain satisfactory photographs. Figure 36 shows a secondary branch with its three ''bodies'' opened out. The segments referred to as valves are in fact pinnules and bear sporangia on their inner surface.

In only one or two cases has it been possible to detect the segmented (pinnular) nature of the globose bodies prior to maceration. The separation of the individual pinnules upon maceration is, however, always uniform and can in no wise be attributed to a maceration artifact. In only two instances have all of the sporangia been observed in place on a pinnule, one of which is shown in fig. 38. The sporangia are arranged in two rows, forming the typical monangial sori of the Schizaeaceae. No evidence of an indusium has been observed. Upon further maceration the sporangia go almost completely to pieces. The maceration residue, however, reveals two structures of considerable interest, spores and more or less complete annuli.

The spores (figs. 6–12) are beautifully preserved, the entire exine being sculptured with characteristic ridges. These are well brought out in the photographs of opposite sides of the same spore (figs. 7 and 8). The triradiate commissure is well defined. Of 50 particularly well-preserved spores that were measured, the average diameter was found to be 40 μ. There is, however, considerable range in size of the spores (from 25 to 47 μ in diameter), as may be noted from the figures where all are shown at the same magnification.

The annuli are also abundant in the residue, the rest of the sporangia disintegrating almost completely. Due to their opaque nature the annuli (fig. 33) are not the best of photographic subjects and are always split open, apparently along the stomium.

It may be seen then that the structures referred to above as primary and secondary branches are, according to usual fern terminology, secondary and tertiary pinnae, and the sporangia are borne on the under-surface of the ultimate divisions or pinnules. The structure of the pinnules, arrangement of the sporangia, nature of the annulus, and characteristic sculpturing of the spores leave no doubt as to the schizaeaceous affinities of the fossil, and of the four living genera of the family, it is clearly more closely related to *Anemia* than any of the other three. The specimen shown in fig. 3 is comparable in every respect with one of the two basal fertile pinnae characteristic of the species of that genus.

The authors are well aware of the inadvisability in general of placing great weight on the association of isolated parts of fossil plants. In this case, however, the above-described fructifications were found associated with, and only with, the foliage described by Knowlton as *Anemia Fremonti* (figs. 35, 39). The two were found together at three different points between ¼ and ½ mile south of Little Muddy Creek. A comparison of the sterile frond (fig. 39) with certain living species such as *Anemia adiantifolia* Swartz in itself leaves little doubt as to the validity of Knowlton's generic identification. This similarity, combined with our discovery of fertile pinnae whose characteristics clearly point to the same genus and which are constantly associated with the foliage, stands as a credit to Knowlton's original identification and seems to render superfluous a new specific name for the fertile specimens.

The evidence at hand strongly supports the supposition that these sterile and fertile parts are one and the same species, but in view of the lack of organic connection it is advisable to employ some sort of nomenclatorial segregation. To assign a new specific name to the fertile parts tends to defeat rather than enhance the ideals of such an investigation, and, moreover, implies a distinction that the available evidence does not support. In accordance with the remaining element of doubt we propose to designate the fertile specimens as a distinct form, namely forma *fertilis*. The problem of interpreting the association of scattered parts of fossil plants is one that the paleobotanist frequently encounters, and it is probably true that most workers are inclined to place too much weight upon such associations. We believe that the procedure employed here does not exaggerate the truth yet does reflect the implications that the evidence affords.

It has been assumed in the restoration (fig. 40) that the specimen shown in fig. 3 is a nearly complete fertile pinna and that the pinnae were borne in pairs as in the modern species. It is quite certain that fig. 3 represents a fairly young pinna since fragments of comparable size when macerated still contained large quantities of spores; furthermore other pinnae have been found, a single secondary one being shown in fig. 4, in which the whole has elongated considerably.

The largest fragment of foliage that we have found is shown in fig. 39. This and numerous other specimens served as the basis of the restoration of the sterile portion of the frond. It may be that the lower sterile pinnae were more deeply dissected than is actually represented.

Fossil history of the Schizaeaceae.—

Our knowledge of the earliest members of the Schizaeaceae has been considerably augmented by the recent researches of Radforth ('38, '39). He has shown that *Dactylotheca Sturi* Sterzel and *D. plumosa* Artis are actually annulate and consequently referable to *Senftenbergia*. There has, in the past, been some doubt as to the affinities of that genus but Radforth's investigations leave no doubt as to its proper inclusion in the Schizaeaceae.

The discovery that *Senftenbergia (Dactylotheca) Sturi* has annulate sporangia extends the history of the family back into Lower Carboniferous (Carboniferous Limestone Series) times. The apical annulus consists of a single row of cells in the modern genera *Anemia, Schizaea* and *Lygonium.* However, Radforth has shown that *Senftenbergia pinnaeformis,* an Upper Carboniferous form, had an annulus of two rows of cells, while *S. Sturi,* from the Lower Carboniferous, has a less regular annulus 4 to 5 cells deep. Of particular interest to the present discussion is his conclusion "that a close phylogenetic relationship exists between these fossil Schizaeaceae and the living Schizaeaceae, and of the latter, particularly the genus *Aneimia.*"

In Jurassic rocks the genus *Klukia* is an undoubted representative of the family and seems to have been rather widespread, specimens having been reported from Yorkshire, Poland, Caucasia and Korea (?).

From the Lower Cretaceous of Virginia, Berry ('11) has described a fertile frond under the name of *Schizaeopsis expansa* (Font.) Berry. This fossil is rather closely comparable to living species such as *Schizaea elegans,* judging from the general morphology of the frond and the sculpturing of the spores.

Stopes and Fujii ('10) described a schizaeaceous fern, *Schizaeopteris mesozoica,* from the Cretaceous of Japan which seems closest to *Anemia.*

Much just criticism has been aimed at the determination of fossil plants based on sterile material but confirmation of Knowlton's identification of *Anemia Fremonti* indicates that even with sterile foliage all is not guesswork. In view of this confirmation in the case of the Frontier formation species we have checked through Knowlton's ('19) list of supposed species of *Anemia* from America. Judging from the published figures there is a reasonable degree of certainty that the following are correctly referred to that genus:

Anemia elongata (Newberry) Knowlton—
Laramie formation, uppermost Cretaceous: Erie, Colo. (?), Point of Rocks, Wyo. (?). (Knowlton, F. H., U. S. Geol. Surv. Prof. Paper 130: *pl. 2, fig. 2.* 1922).

Aneimia eocenica Berry—
Lagrange formation, basal Eocene: Puryear, Tenn. (Berry, E. W., U. S. Geol. Surv. Prof. Paper 91: *pl. 10, fig. 2, pl. 11, figs. 1, 2.* 1916).

Anemia hesperia Knowlton—
Fruitland formation, Upper Cretaceous: San Juan Co., N. M. (Knowlton, F. H., U. S. Geol. Surv. Prof. Paper 98: *pl. 84, fig. 3.* 1916).

Anemia occidentalis Knowlton—
Raton formation, Paleocene: Trinidad, Colo., Yankee, N. M. (Knowlton, F. H., U. S. Geol. Surv. Prof. Paper 101: *pl. 54, fig. 2.* 1917).

Anemia supercretacea Hollick—
Vermejo formation, Upper Cretaceous: Rockvale, Colo. (Knowlton, F. H., U. S. Geol. Surv. Prof. Paper 101: *pl. 30, fig. 5.* 1917).

It is thus clear that the family Schizaeaceae, and particularly the genus *Anemia,* once enjoyed a much more northerly distribution than at present. *Anemia* is now confined to the American tropics and subtropics (with the exception of one species from South Africa), extending northward only into the southern part of the United States.

Anemia sp.

Fragments of fronds have been found at a number of points along the outcrop, which are closely comparable with certain living species of *Anemia.* Although similar in certain respects to *A. Fremonti* they are much less robust and have not been found associated with the fertile pinnae of the latter.

The most complete specimens that we have discovered are shown in figs. 30–32, 34. Those shown in the first two figures probably represent nearly complete fronds which are characterized by a rather long slender stalk, twice pinnate, with a tendency toward a tertiary division in the basal pinnae (fig. 31). It is quite possible that these fronds are simply small specimens of *A. Fremonti* but since they have not been found closely associated with that species it seems best to describe them separately. There is, moreover, a striking similarity to the Wealden fern, *Ruffordia Goepperti,* which Seward ('94) likewise includes in the Schizaeaceae.

GLEICHENIACEAE

Gleichenites coloradensis (Knowlton) Andrews, n. comb.

Dryopteris coloradensis Knowlton, U. S. Geol. Surv. Prof. Paper 108-F: 83, *pl. 30, figs. 3, 4.* 1917.

This apparent fern was included by Knowlton in the Polypodiaceae, a justifiable conclusion considering the fragments of foliage that he had available for study. Although our specimens do not bear reproductive structures, a considerable amount of information has been obtained concerning the structure of the frond as a whole. As may be judged from the following description, it is strikingly similar vegetatively to certain species of *Gleichenia,* the resemblance being sufficiently great to warrant its transference from *Dryopteris* to the genus *Gleichenites* of Goeppert.

Collections were made at three localities along the plant-bearing outcrop, at points approximately 1½, 1¾ and 2 miles north of Little Muddy Creek. Most of our material came from the last two localities where it occurred as a "pure stand," there being no other associated fossil plants.

Knowlton did recognize that it was a plant of considerable size. He writes, "From the presence of large pieces of stems intermingled with the fronds and presumed to belong to them, it is assumed that this fern was probably of large size, but the direct evidence is only sufficient to say that it is at least bipinnatifid." In all probability the "large pieces of stems" that Knowlton mentions are fragments of the rachis. The most distinctive feature of the frond lies in its successive trichotomous-like branchings. The rachis is of considerable size, as may be noted in figs. 20 and 26, a number of fragments similar to that shown in fig. 26 having been found. The central member of the "trichotomy" may grow out (fig. 20) or remain abortive (figs. 21, 24), but it does seem to have been more generally developed in the fossil than in living species such as *Gleichenia pectinata.*

In the reconstruction of the frond in fig. 21 it has been assumed that *c* corresponds to the primary subdivisions of the specimens shown in figs. 20 and 26. The specimen shows three further divisions, the last of which lies on the counterpart of the specimen and is shown at *b,* fig. 22 (the negative has been reversed so as to show it in the same orientation as fig. 21). The pinnules are arranged on the ultimate (fourth order) subdivisions as shown in figs. 24, 27. Figure 29 has been included to show more clearly the typical pinnule morphology.

The removal of this species from the genus *Dryopteris* seems fully justifiable in view of our present knowledge of the structure of the frond. Had Knowlton had more complete specimens he would undoubtedly have placed it in the Gleicheniaceae. Because of the fact that sporangia still remain to be discovered it seems best to refer the plant to *Gleichenites.*

Of the various species of *Gleichenites* that have been described (Hirmer, '27, pp. 623–4), *G. coloradensis* compares most closely with *G. Gieseckiana* Heer. The characteristic mode of branching, as well as the morphology of the pinnules, is very similar to specimens of the latter described by Seward ('26) from the Cretaceous of Greenland. It was apparently a widespread species during Cretaceous times, specimens having been reported from Spitsbergen, England, France, Germany, Russia, Sakhalin (Japan), Dakota and New Jersey (Seward, '26, p. 147). In view of this circumpolar distribution of *G. Gieseckiana,* it is not surprising to find the very similar, if not identical, *G. coloradensis* in the Upper Cretaceous of southwestern Wyoming.

Where reconstructions of fossil plants or parts thereof can be prepared with a reasonable degree of accuracy it seems desirable that the plant be presented in that fashion. The figured specimens, as well as numerous others from which information has been drawn, bear out the accuracy of our restoration of the frond as we believe it appeared in life (fig. 41). Whether or not the entire frond is represented is, of course, not certain. As our material indicates but four orders of branching, only that many have been shown, and since no rachis fragments larger than those shown in figs. 20 and 26 have been found it is likely that the entire frond is represented. Some of the terminal branches have been eliminated in the restoration in order that the structure of the terminal pinnae might be brought out more clearly.

The distinctive morphology of the fronds, as well as the sori and sporangia of *Gleichenia,* has enabled its scattered fossil remains to be assembled into one of the most interesting stories of geographical distribution presented by an extant genus. Confined now to the tropics and sub-tropics, *Gleichenia* once enjoyed a range far north of its present confines. It has been described from Jurassic and Cretaceous rocks of Greenland, and from the Cretaceous period numerous localities in North America, to mention a few: Maryland, New Jersey, Kansas, Colorado, Wyoming, California, British Columbia.

In 1935 Seward wrote, "The sight of well preserved fronds of Ferns with forked arms exposed on a slab of shale on the beach of Upernivik Island (71° N. lat.) took me back to a hillside above Penang in the Malay Peninsula, where living Gleichenias in company with *Dipteris* formed a wonderful tangled carpet of luxuriant growth on the edge of a tropical forest." No more striking contrast to either the arctic or tropical climates could be found than the present semi-desert sagebrush hills of southwestern Wyoming whose climate must have been much more like that of Penang in Upper Cretaceous times than it is at present.

CYATHEACEAE-DICKSONIACEAE

Microtaenia Knowlton

In his account of the Frontier flora Knowlton described two species under this genus, *M. variabilis* and *M. paucifolia* (Hall). In both cases apparently fertile fronds were described and figured but no actual evidence of their fertility was given. As we have succeeded in isolating spores from both species a further account of these interesting ferns is presented here.

Microtaenia paucifolia (Hall) Knowlton, U. S. Geol. Surv. Prof. Paper 108-F: 82–83, *pl. 30, figs. 1, 2.* 1917.

Fertile fragments of this species were found to be fairly abundant, particularly within a radius of ½ mile to the north and south of Little Muddy Creek. The greatest part of the fragments apparently had matured previous to fossilization since of the numerous ones collected only two have yielded spores. The largest specimen (fig. 16) was deposited before spore dispersal as spores have been found in all of the sori studied. When the large globose bodies terminating the pinnules were removed from the rock and macerated in nitric acid and potassium chlorate for a few minutes, a residue of spores resulted (fig. 17). The triradiate commissure is clearly shown. The exine is rather delicate and smooth, with no evidence of sculpturing of any sort. All the spores are distinctly triangular as shown in the figure, and although this may be due in part to collapse it may represent the actual shape of the spore in life. There is very little variation in spore size, all being about 26 μ in diameter.

No evidences of sporangia have been found in the globose terminal supposed sori. There remains the possibility that the "sori" are actually single terminal sporangia. There is a striking resemblance of these structures to the Jurassic genus *Coniopteris,* particularly of *C. hymenophylloides* (see Thomas, '11, *pl. 3, figs. 1, 4, 5;* Seward, '00, *pl. 17, fig. 8).* However, no foliage has been found in the Frontier formation which compares at all closely with that of *Coniopteris.* Because of the close similarity between *Microtaenia paucifolia* and the fertile pinnae of *Coniopteris hymenophylloides,* which is generally accepted as being referable to the Dicksoniaceae, it seems advisable to include *Microtaenia* within that family instead of the Polypodiaceae following Knowlton's classification.

Microtaenia variabilis Knowlton

Only two fertile fragments of this plant are included in our collection. Figure 13 shows one of these magnified nearly 5 times and fig. 14 is a portion magnified 24 times. It differs from *M. paucifolia* in the broader, more leaf-like nature of the pinnae. In fig. 14 a single vein may be seen passing out to each sorus.

Sporangia have not been observed but a few spores have been obtained. Their walls are delicate and wrinkled (fig. 15) and there is no evidence of sculpturing or a triradiate commissure.

EQUISETACEAE

Equisetum sp.

In his report on the Frontier plants Knowlton described and figured a species of *Equisetum* based on a supposed underground stem. In our collection of the past summer we have a specimen referable to his species, but it is far from being a convincing representative of the genus. Other specimens have been found, however, of a much less doubtful nature. A nodal diaphragm is shown in fig. 18. This was associated with rather poorly preserved stem fragments which, although a specific name would be meaningless, does attest to the presence of the genus in the flora.

PLANTAE INCERTAE SEDIS

Baiera sp. (?)

The problematical specimens described under this name were found at only one locality, about 1½ miles north of Little Muddy Creek. The most complete specimen that was collected is shown in fig. 28. It may be noted that this dichotomizes five times and, as in the other specimens illustrated (figs. 19, 23, 25), the branching is equal or nearly so in all cases.

In the right-hand primary fork of the specimen shown in fig. 28 a single vein may be discerned in each subdivision. The vein divides some distance before reaching the dichotomy of the lamina (this term is employed on the assumption that the fossil does represent a leaf of the *Baiera* type). Unfortunately, the fossils are preserved in a coarse sandy shale, there being no cuticular remains.

There is a close superficial similarity between our specimens and certain species of *Baiera,* particularly *B. spectabilis* (Walton, '40, *fig. 124a)* and a specimen tentatively referred by Seward to *B. Lindleyana* (Seward, '26, *pl. 10, fig. 101).* There are, however, other possibilities that merit consideration.

In 1895 Seward described, under the name of *Becklesia anomala,* a fossil plant from the Wealden of England, consisting of a central axis with pinnately arranged branches which in some cases "appear to bifurcate close to the point of attachment to the central axis." He compared his specimen with the peculiar forked leaflets of the living *Macrozamia heteromera* Moore. A study of herbarium specimens of the latter revealed a rather striking similarity although the Frontier fossils are somewhat larger and appear to have been more laxly disposed.

Summary

The preceding is an account of certain fossil plants from the Upper Cretaceous Frontier formation of Wyoming. Well-preserved compressions of fertile pinnae of a schizaeaceous fern are described and shown to be referable to *Anemia Fremonti* Knowlton. Since the sterile and fertile parts of the frond have not been found in actual organic connection the latter are described as forma *fertilis.*

Fronds of the supposed polypodiaceous fern *Dryopteris coloradensis* Knowlton are shown to possess vegetative characters distinctive of *Gleichenia* and are redescribed as *Gleichenites coloradensis.*

Spores have been obtained from the fertile fronds of *Microtaenia variabilis* Knowlton and *M. paucifolia* (Hall) Knowlton.

The presence of *Equisetum* in the flora is recorded and fossils referable to *Baiera* are described.

Acknowledgment

For the carefully prepared drawings composing plates 6 and 7 we are especially grateful to Mr. Albert A. Heinze.

Literature Cited

Berry, E. W. (1911). A Lower Cretaceous species of Schizaeaceae from eastern North America. Ann. Bot. **25**: 193–198.

Hirmer, M. (1927). Handbuch der Palaobotanik. München.

Knowlton, F. H. (1917). A fossil flora from the Frontier formation of southwestern Wyoming. U. S. Geol. Surv. Prof. Paper 108-F: 73–94.

————, (1919). A catalogue of the Mesozoic and Cenozoic plants of North America. U. S. Geol. Surv. Bull. 696.

Radforth, N. W. (1938). An analysis and comparison of the structural features of *Dactylotheca plumosa* Artis sp. and *Senftenbergia ophiodermatica* Goeppert sp. Trans. Roy. Soc. Edinb. **59**: 385–396.

——————, (1939). Further contributions to our knowledge of the fossil Schizaeaceae; genus *Senftenbergia*. *Ibid.* **59**: 745–761.

Seward, A. C. (1894). The Wealden Flora. Cat. Mes. Pl. Geol. Dept. Brit. Mus. I.

——————, (1895). *Ibid.* II.

——————, (1900). The Jurassic Flora. I. The Yorkshire Coast. *Ibid.* III.

——————, (1926). The Cretaceous plant-bearing rocks of western Greenland. Phil. Trans. Roy. Soc. Lond. **B215**: 57–175.

——————, (1935). Selections from the story of plant migration revealed by fossils. Sci. Prog. **30**: 193–217.

Stopes, M. C., and K. Fujii (1910). Studies on the structure and affinities of Cretaceous plants. Phil. Trans. Roy. Soc. Lond. **B201**: 1–90.

Thomas, H. H. (1911). On the spores of some Jurassic ferns. Proc. Cambridge Phil. Soc. **16**: 384–388.

Veatch, A. C. (1907). Geography and geology of a portion of southwestern Wyoming. U. S. Geol. Surv. Prof. Paper 56: 1–178.

Walton, John (1940). An introduction to the study of fossil plants. London.

Explanation of Plate

PLATE 1

Anemia Fremonti Knowlton forma *fertilis* Andrews.

Fig. 1. Two primary branches of fertile pinna. Photograph from a nitrocellulose transfer. No. 1312, × 4.

Fig. 2. Primary branch of fertile pinna. Only one pinnule cluster is shown on each secondary branch, the others having been removed with the counterpart, lost prior to fossilization, or are deeply imbedded in the matrix. No. 1309, × 3.3.

Fig. 3. A nearly complete young fertile pinna. No. 1313, × 3.

Fig. 4. Primary branch of a somewhat older fertile pinna, as evidenced by its greater size and more expanded condition of the pinnule clusters. Two of the latter may be clearly distinguished on most of the secondary branches. No. 826, × 3.2.

Fig. 5. Primary branch of a fertile pinna. Photograph from a nitrocellulose transfer. No. 1311, × 4.

ANDREWS & PEARSALL—FLORA OF FRONTIER FORMATION

Explanation of Plate

PLATE 2

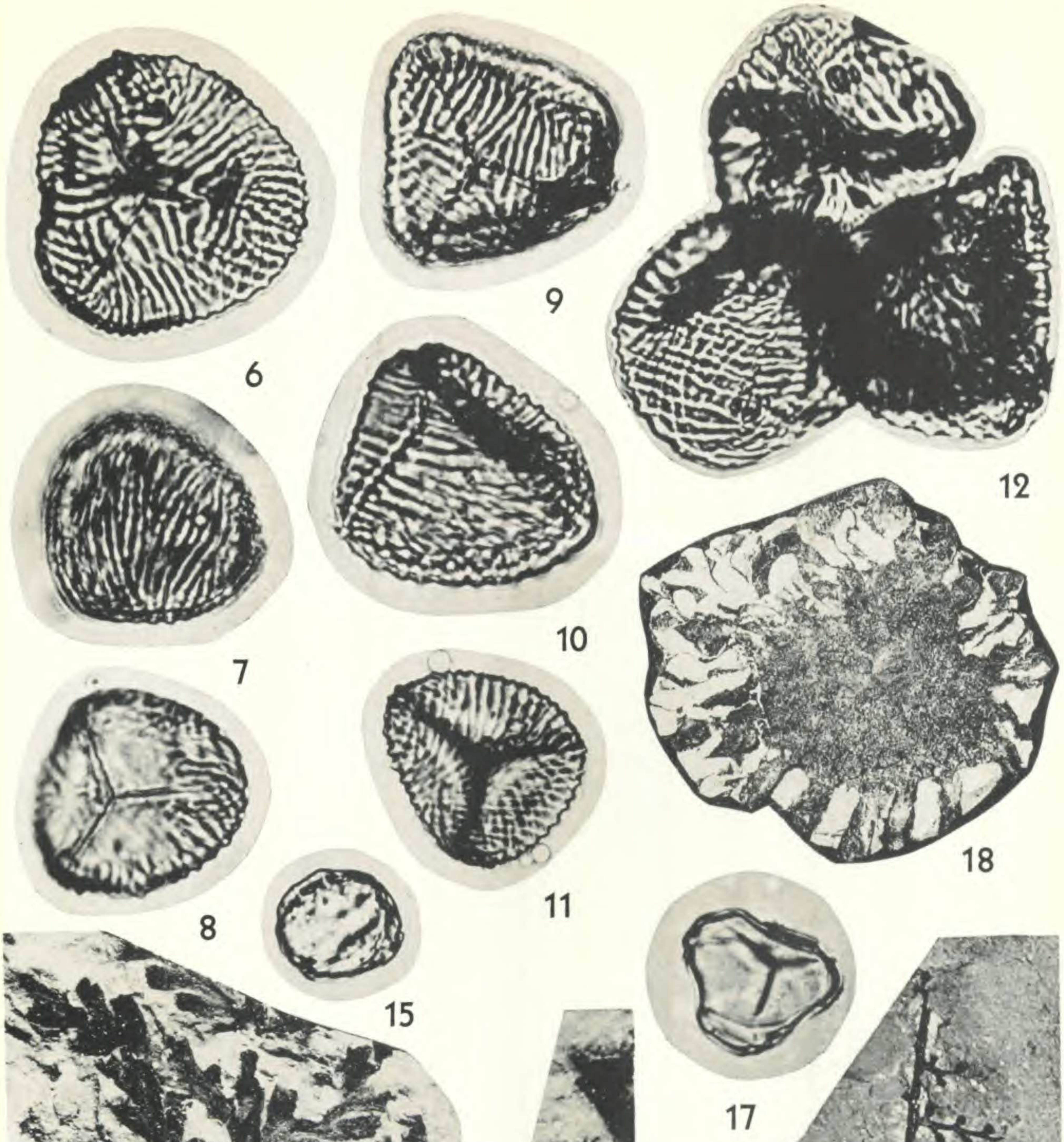
Figs. 6–12. Spores of *Anemia Fremonti* forma *fertilis*. Figs. 7 and 8 are of opposite sides of the same spore. Fig. 12 is of a tetrad, all × 750.

Figs. 13–15. *Microtaenia variabilis* Knowlton. Fig. 13. Portion of fertile frond. No. 1308, × 4.8. Fig. 14. Portion of same more highly magnified, × 24. Fig. 15. Spore, × 750.

Fig. 16. *Microtaenia paucifolia* Knowlton. Portion of fertile frond showing the large, terminal, globose sori (or sporangia?). No. 1310, × 1.7.

Fig. 17. Spore of same, × 750.

Fig. 18. *Equisetum* sp. nodal diaphragm, × 2.3.



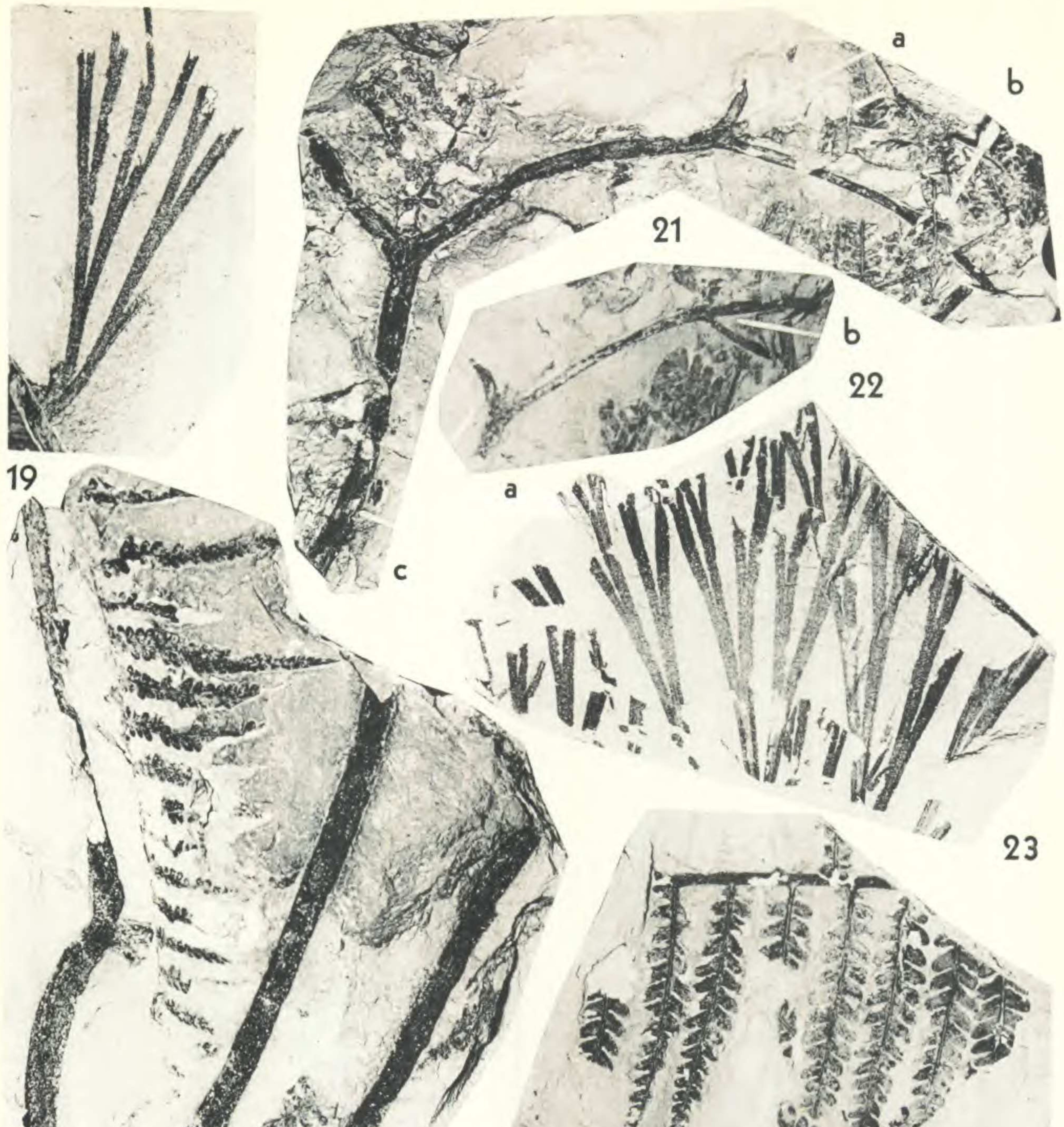
ANDREWS & PEARSALL—FLORA OF FRONTIER FORMATION

Explanation of Plate

PLATE 3

Figs. 19, 23. *Baiera* sp. Fig. 19. No. 1302, × 1.3. Fig. 23. No. 1301, × 1.

Figs. 20, 21, 22, 24. *Gleichenites coloradensis* (Knowlton) Andrews. Fig. 20. Basal portion of frond showing primary branching. No. 1296. Fig. 21. Portion of frond showing secondary and tertiary branch. No. 1293. Fig. 22. Photograph of the counterpart of the specimen shown in fig. 21. The negative was reversed in order to show the two in the same orientation. No. 1294. Fig. 22*a* corresponds to fig. 21*a*, while the fourth order of branching is shown at fig. 22*b*. Fig. 24. Final (fourth) branching showing pinnule morphology. No. 1298. All approx. × .8.



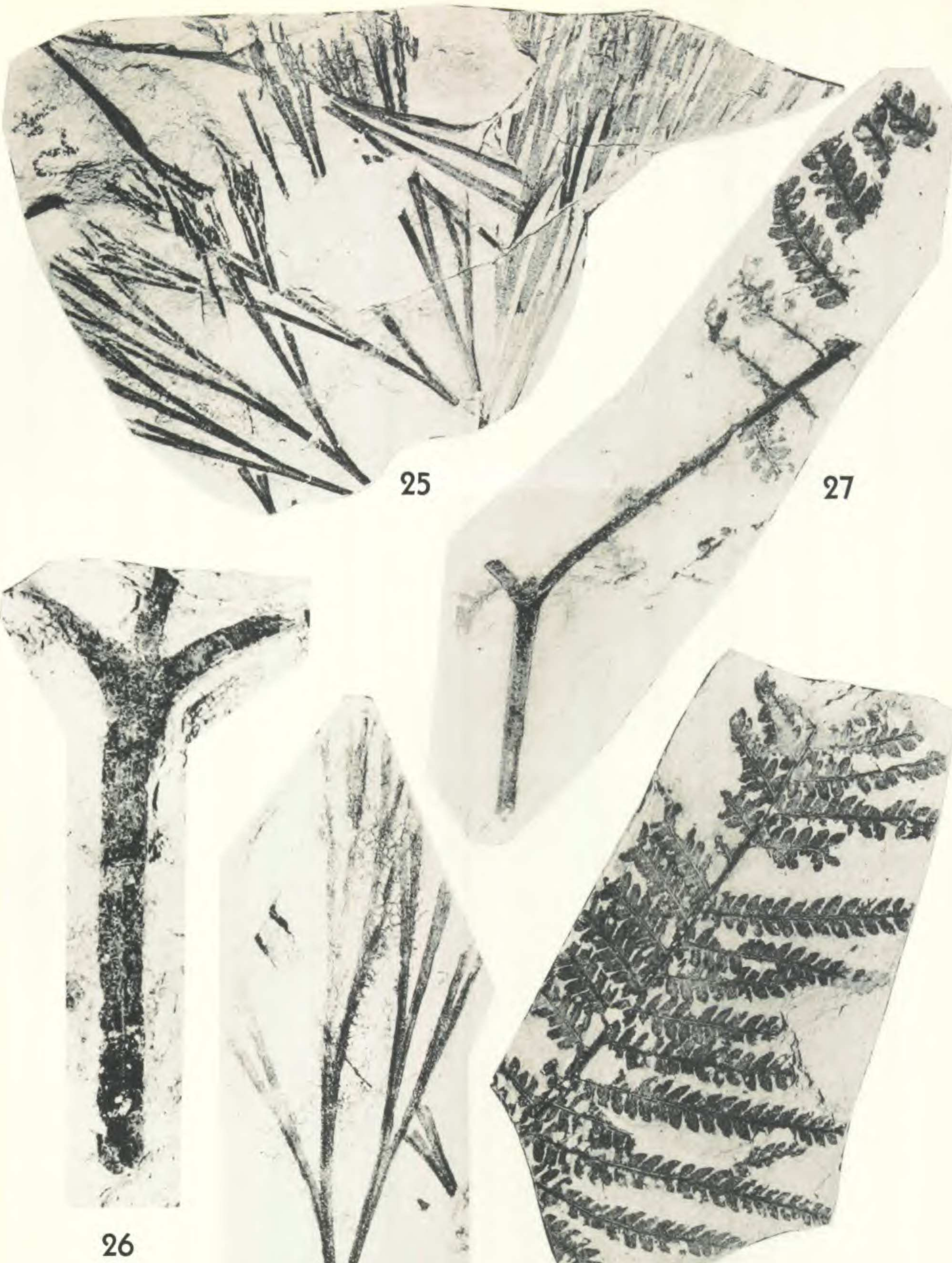
ANDREWS & PEARSALL—FLORA OF FRONTIER FORMATION

Explanation of Plate

PLATE 4

Figs. 25, 28. *Baiera* sp. Fig. 25. No. 1304, × 1. Fig. 28. No. 1303, × 1.4.

Figs. 26, 27, 29. *Gleichenites coloradensis.* Fig. 26. Primary branching of frond. No. 1292, × 1. Fig. 27. Fourth order of branching. No. 1291, × 1. Fig. 29. Portion of a terminal branch showing pinnule morphology. No. 1297, × .9.



ANDREWS & PEARSALL—FLORA OF FRONTIER FORMATION

EXPLANATION OF PLATE

PLATE 5

Figs. 30, 31, 32, 34. *Anemia* sp. Portions of sterile fronds. Explanation in text. Fig. 30. No. 1300, × 1. Fig. 31. No. 1299, × 1. Fig. 32. No. 1307, × 1. Fig. 34. No. 1295, × .9.

Fig. 33. *Anemia Fremonti* forma *fertilis*. Annulus, × 160.

Fig. 35. *Anemia Fremonti*. Terminal portion of frond. No. 1305, × 1.

30

31

32

33

34

35

ANDREWS & PEARSALL—FLORA OF FRONTIER FORMATION

Explanation of Plate

PLATE 6

Figs. 36–38. *Anemia Fremonti* forma *fertilis*. Fig. 36. Portion of primary branch of a fertile pinna showing a secondary branch after treatment with macerating fluid, × 15. Fig. 37. A single pinnule cluster in side view showing the sporangia arranged in two rows along the under-surface of the pinnules, × 30. Fig. 38. Under-surface of a single pinnule, × 30.

Fig. 39. *Anemia Fremonti*. Part of sterile portion of frond. No. 1306, × 1.

Fig. 40. Restoration of complete frond.

ANDREWS & PEARSALL—FLORA OF FRONTIER FORMATION

Explanation of Plate

PLATE 7

Fig. 41. Restoration of frond of *Gleichenites coloradensis*.